NASA-TM-107998

Manned Space Flight Benefits

National Aeronautics and
Space Adminstration

Lyndon B. Johnson Space Center
Houston, Texas

NOTICE: NASA does not endorse commercial products developed as a result of its Technology Utilization or Patent Licensing Programs, but it does encourage the widest possible use of its technology.

ON THE COVER: An example of man working in space. An astronaut mission specialist repairs an orbiting satellite on Space Shuttle mission STS 51-I in August 1985.

Manned Space Flight Benefits

Michele Anderson

RCA Government Services
Houston, Texas

June 1987

CONTENTS

INTRODUCTION

The National Aeronautics and Space Administration (NASA) has developed new technologies for use by the space program which have resulted in spinoffs beneficially affecting the quality of life on Earth. During all phases of flights from launch until landing, the astronauts were in environments which required the development of new techniques, equipment, or procedures to assure their safety during a flight and return to Earth. Some of the factors of the environment to be addressed for manned flight were the physiological effects of weightlessness, breathing systems, thermal regulation of the crew during extravehicular activity (EVA) and lunar excursions, food requirements, toxic possibilities from spacecraft materials in the event of fire, microbiological contamination of the spacecraft cabin, and ocean recovery.

The spinoffs which were selected for this publication benefit human beings by improving their physical capabilities, medical care, safety, environment, and recreational equipment. The information was acquired from the NASA Spinoff publications issued yearly by the Technology Utilization and Industry Affairs Division at NASA Headquarters. The state of the art of some of the technologies has improved since some of the spinoffs were developed. This historical perspective does not trace the finer improvements which have occurred in some areas. There are examples of spinoffs in the development stage which had beneficial applications and were being tested by hospitals and research institutions but proved not to be suitable for commercial development for a variety of reasons.

Five NASA technologies were selected for this publication: Telemetry, Imaging and Scanning Techniques, Equipment and Instrumentation, Materials, and Special Technologies. These technologies have produced spinoffs in many fields of research which have improved living conditions on Earth such as crop and resources management and weather tracking and reporting. The spinoffs selected for this publication are based on technology developed to provide a safe environment for astronauts working in space or to directly help human beings on Earth. It is interesting to note that some of the spinoffs used a combination of these technologies.

The developers of the spinoffs are listed in the index, although, over the years, the company's name may have changed or the company may have been acquired by another company. There are also several companies who are marketing similar products such as the exercise equipment and the anti-fog coatings.

The NASA centers have active research and development programs which continually yield new techniques or inventions leading to the development of spinoffs. The results of these programs are reported quarterly in NASA Tech Briefs, another publication issued by the Technology Utilization and Industry Affairs Division. Potential products, industrial processes, basic and applied research, shop and laboratory techniques, computer software, and new sources of technical data and concepts are described in Tech Briefs.

This collection of information may stimulate new ideas which often come about by combining developments in seemingly unrelated research areas or may provide a catalyst for the improvement of existing spinoffs. With the possibility of having a permanently manned Space Station and manned expeditions to Mars, the opportunity is unlimited for the continual development of new spinoffs.

TELEMETRY

Telemetry is a process for sending or receiving measurements from remote locations by using electronic equipment. The equipment converts data to coded signals which are transmitted by radio or wire, picked up by an antenna, fed into a receiver, and decoded to become useful information. A telemetry system can be interrogated by signals or it can be commanded to perform some function.

Telemetry has been used for many years, but with the beginning of the space age when Sputnik was launched by the Soviet Union in 1957, telemetry took on a new meaning when it was used to track the location of the satellite in orbit around the Earth. The Echo 1 satellite, launched in 1960, was NASA's first experiment in satellite communications. The satellite served as a space relay station for reflecting signals from one point on Earth to another.

As space activities progressed, the use and complexity of telemetry expanded for each new space application. The Pioneer, Viking, and Voyager programs relied on telemetry for adjusting the flightpaths of these spacecraft and for receiving pictures of the planets.

Biotelemetry, a method of acquiring physiological measurements, was used during the manned space programs to monitor electrocardiograms (EKG's), heart rates, and respiratory patterns and rates of the astronauts during critical phases of a mission such as launch, docking, EVA, and lunar explorations. Television observations and monitoring of vital signs provided the medical basis for an in-flight clinical profile of the astronauts' physical condition.

The spinoffs developed from telemetry can be divided into several specialized areas. Telemetry is used for medical monitoring of patients in hospitals, ambulances, or clinics which do not have full hospital services and for medical treatment of patients in remote locations by physicians who advise health care specialists. Another area is the use of telemetry to communicate with or program physically implanted instruments such as pacemakers, tissue stimulators, or medication systems. Telemetry also is used with communications networks to respond to people in need of assistance.

REMOTE MEDICAL MONITORING

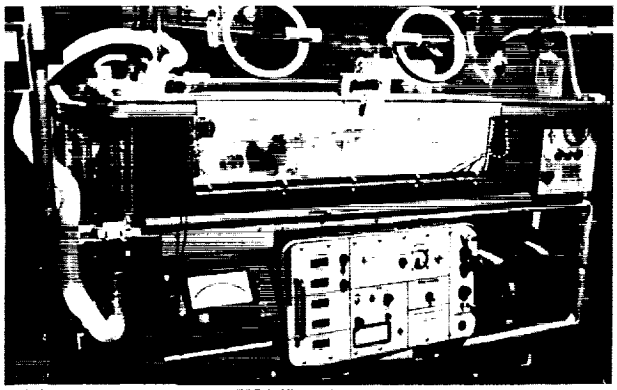
Patient Monitoring System

Electrocardiograms of a hospitalized patient are transmitted by telemetry using the Patient Monitoring System. Heart readings are picked up by an electrode attached to the patient's body and delivered by wire to a small box. The signals are relayed wirelessly to a console which converts them to EKG data, and, at the same time, they are transmitted to a central control station, where a nurse can monitor the condition of several patients simultaneously. The data are displayed visually and recorded on a printout.

Patient Monitoring System.

Pediatric Monitoring and Transport System

Premature babies and other babies who become ill soon after birth require intensive care and treatment which most community hospitals cannot provide. Movement of infants from outlying areas may take hours by ambulance; even airplane and helicopter flights may be lengthy. The Pediatric Monitoring and Transport System is a multifaceted system which places the infant under constant direct and remote supervision during a trip to the hospital The system includes a special incubator, a trained intern or nurse, a portable biotelemetry unit, a transmission system for voice or telemetry signals, microwave towers for communications relay, and a monitoring base station at a central hospital. The infant's vital data are sent continuously to the hospital, where they are displayed on a console and recorded on cassettes and a strip chart recorder. The monitoring process continues after arrival at the hospital and during surgery or intensive care.

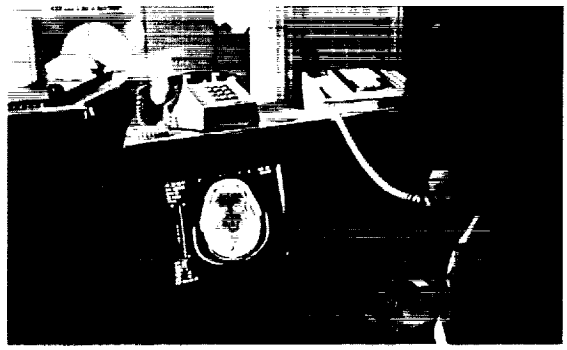


Pediatric Monitoring and Transport System.

Slow Scan Telemedicine

Computer tomography (CT) scans of patients are transmitted over telephone lines, radio, microwave, and satellite channels to television (TV) monitors for remote analysis by physicians. Slow Scan TV takes 30 seconds to a minute to transmit a single still frame. The system consists of a standard closed-circuit camera connected to a device called a scan converter, which slows the stream of images to match an audio circuit, such as a telephone line. Transmitted to its destination, the image is reconverted by another scan converter and displayed on a TV monitor. Slow Scan operating costs are a little more than the expense of a phone call because of narrow-band transmission.

In addition to CT scans, the technique allows transmission of x-rays, nuclear scans, ultrasonic imagery, thermograms, electrocardiograms, or live views of a patient. Such transmissions enable extension of physicians' and specialists' services to remote communities through paramedics or nurses at clinics equipped with a Slow Scan system.



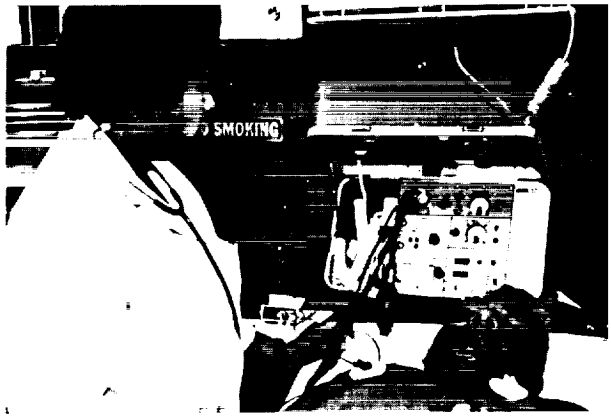
Slow Scan Telemedicine.

REMOTE MEDICAL TREATMENT

Space Technology Applied to Rural Papago Health Care (STARPAHC)

STARPAHC applies space technology to providing health care for villages of the Papago Indian Reservation in Arizona which are located in a very remote area. A key element of STARPAHC is the Mobile Health Unit, a large van containing clinical equipment and communications gear for contact with STARPAHC's base of operations, the Indian Hospital at Sells, Arizona. The mobile clinic visits

the villages on a preannounced schedule and handles as many as 27 patients a day. Patients' vital data can be sent via a telecommunications network to physicians monitoring consoles in the hospital. Television and x-ray pictures may also be transmitted. The physician can see, talk with, and, in a figurative sense, "touch" the patient. The physician makes a diagnosis and specifies treatment be to performed in the Mobile Health Unit.



STARPAHC.

Portable Medical Status and Treatment System

The Portable Medical Status and Treatment System incorporates NASA's astronaut monitoring, electronic circuitry, telemetry, and microminiaturization technologies. The system, which includes a vital signs monitor and a defibrillator, is designed for remote use when considerable time may elapse before a patient can be transported to a hospital. Pulse rate, temperature, blood pressure, and respiration rate are displayed on a 5-inch scope which includes heart rate and respiration rate alarms. The 10-channel radio with 2-way communication allows transmission of vital signs to a distantly located physician, who provides diagnosis and treatment instructions to an attendant at the scene of an emergency. This system is a further refinement of one of the earliest spinoffs developed from the medical care techniques for astronauts, the "Physician's Black Bag." Included in the bag are an electronic vital signs monitor, a cassette recorder for recording electroencephalograms, equipment for minor surgery, and conventional diagnostic instruments. A built-in telephone coupler is used for data transmission over a standard telephone line.

Portable Medical Status and Treatment System.

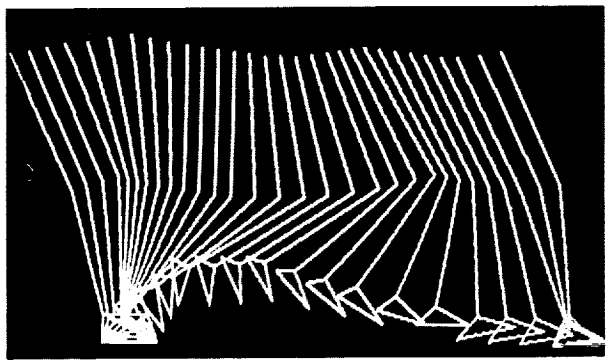
MEDICAL EQUIPMENT

Miniature Sensors/Transmitters

To accurately record the abnormal walking pattern of children afflicted with cerebral palsy, muscular dystrophy, or congenital disorders, transmitters, about the diameter of a half dollar, are placed over the muscle group to be analyzed. Step-sensing switches are inserted in the soles of the shoes. Each transmitter has its own battery and a pair of sensing electrodes. Because they are small and lightweight, several transmitters can be used to measure the degree and location of abnormal muscle activity from both legs simultaneously. An electromyogram signal indicating the activity of the leg muscles is sent by biotelemetry to a computer, which develops video images of the walking pattern. The system offers

a means of unencumbered recording of the true gait pattern of a child which is helpful to the physical therapist and orthopedic surgeon in determining the need for muscle and tendon lengthening operations, in evaluating various types of braces, and in deciding whether certain muscle-relaxing drugs might prove effective.

Miniature sensors/transmitters.



Gait analysis

Programalith

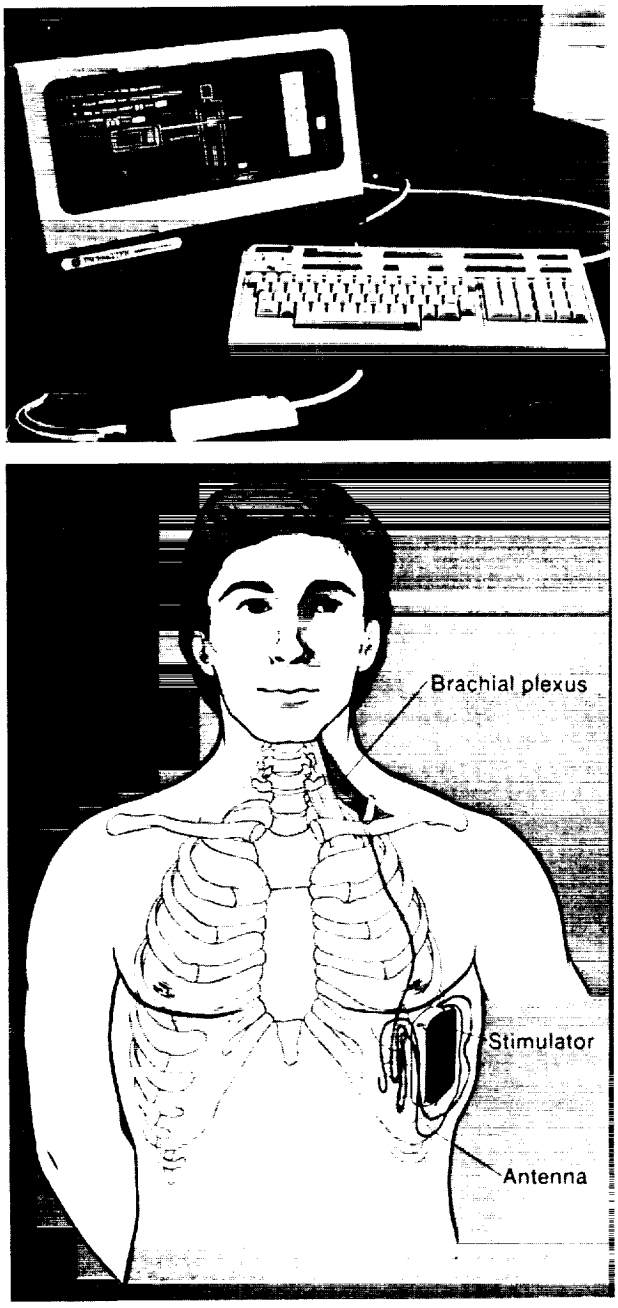
Programalith is a cardiac pacing system which allows a physician to reprogram a patient's implanted heart pacemaker using telemetry. It has two-way communications capability enabling surgery-free "fine tuning" of the device to best suit the patient's needs, which may change over time with changes in physical condition. The system consists of the implantable pacemaker together with a physician's console containing the programmer and a data printer. A communications head held over the patient's chest permits the physician to communicate with the pacemaker. As many as six different parameters of the pacemaker can be reset. The physician can interrogate the device regarding the status of its interaction with the heart as well as determine how much life remains in the pacemaker's battery. The pacemaker will only accept properly coded instructions and will not respond to false signals generated by electrical noise or other interference.

Programalith.

Human Tissue Stimulator

The Human Tissue Stimulator was developed to treat chronic pain and involuntary motion disorders by electrical stimulation. The device, the size of a deck of cards, is implanted in the body. It includes a tiny rechargeable battery, an antenna, and electronics to receive and process commands and to report on its own condition via telemetry. The stimulator sends electrical pulses through wire leads to targeted nerve centers or to particular areas of the brain. This provides relief from intractable pain or arrests involuntary motion. The nickel-cadmium battery can be

recharged through the skin so that frequent surgical replacement is not required. A console is a part of the system and is used to turn the stimulator on and off or to alter the character and strength of the electrical impulses. The Human Tissue Stimulator is designed to provide relief to patients suffering from back, leg, and arm pain, cancer pain, or multiple sclerosis.



Human Tissue Stimulator.

Automatic Implantable Defibrillator

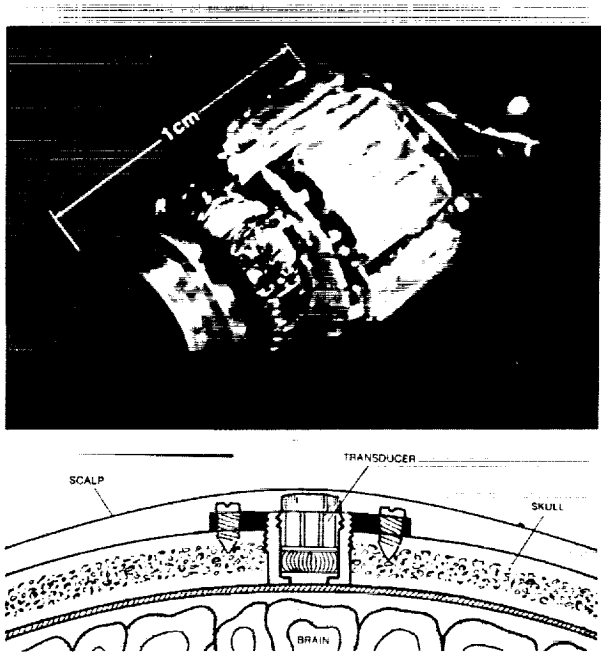
The heart assist device is a miniaturized version of the defibrillator used by emergency teams and hospitals to restore rhythmic heart beat after erratic heart action called ventricular fibrillation occurs. The fibrillating heart loses its ability to pump blood, a condition which causes death or permanent brain damage in a matter of minutes if not immediately corrected. The device is implanted like a pacemaker, monitors the heart continuously, recognizes the onset of fibrillation, and then delivers a corrective electrical shock. The device consists of a microcomputer, a power source, and two electrodes which sense heart activity. An associated system provides a record of fibrillation occurrence and the ensuing defibrillation for use by a physician in prescribing further treatment.

Automatic Implantable Defibrillator.

Brain Pressure Monitor

Brain damage can result from external injury, such as an automobile accident; from internal injury, such as a stroke, infection, or tumor; or as a result of hydrocephalus. In all these cases, brain damage is largely attributable to increased intracranial pressure. A widespread need was recognized to acquire accurate and continuous information on the degree of pressure. The previous method for obtaining pressure included

drilling a hole in the skull and inserting a catheter, which was a source of infection and may have become blocked by shifts in brain tissue. A transducer that is totally implantable was developed. It penetrates the skull but does not enter the dura, the tough membrane that forms a protective cover around the brain tissue. Once the transducer is implanted, the scalp is closed over the device, reducing risk of infection and allowing the patient freedom of movement. The brain pressure is reported by telemetry. The transducer was based on technology developed for NASA to measure air pressure in aircraft wind-tunnel tests.



Brain Pressure Monitor.

Programmable Implantable Medication System (PIMS)

The PIMS is a microminiaturized, computer-directed system for continuous delivery of medication to target organs in precisely controlled amounts from a source implanted in the patient's body. Programming of an infusion pump is accomplished by telemetry. The physician can communicate via a telephone line with the implanted pump's computer. The computer reports stored information to a receiver in the doctor's office. The computer can be interrogated and the medication flow rate can be reprogrammed after the patient's response to treatment has been determined. When the computer reports its medication is running low, the patient returns to the doctor's office for a refill, accomplished by hypodermic injection through the infusion pump's self-sealing membrane. The computer will accept only properly coded instructions. About the size of a cosmetics compact and implanted in the shoulder or abdominal area, the system contains a reservoir of medication, a tiny infusion pump, a tube leading to the target area of the body, a battery, and the computerizing electronic system. The system allows the patient to change his own dosage.

COMMUNICATIONS NETWORKS

Satellite Beacon System

The NASA Nimbus 6 satellite relays signals from a 7-pound beacon to track the location of explorers and adventurers in remote locations. The beacon was used during the flight of the hot-air balloon Double Eagle II on its successful transatlantic flight, by Japanese explorer Naomi Uemura on two Arctic expeditions, and during oceanic yacht races. The hand-held, battery-powered Emergency Location Transmitter allows the receiving satellite to pinpoint the source of the signals. The Nimbus satellite relays the signals to monitors at the NASA Goddard Space Flight Center, where the position of the beacon is computed and sent to centers tracking the progress. The beacons have a special switch to indicate an emergency situation if voice communications using other systems fail to operate. The principal application of the beacons is for improving rescue operations of private aircraft flying over sparsely populated areas.

Satellite Beacon System.

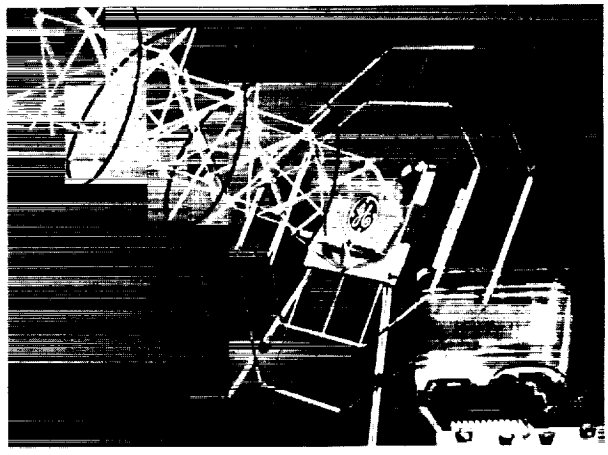
Search and Rescue Aid

An international satellite-aided system for detecting and locating signals from downed aircraft or troubled ships provides a method for continuously monitoring and reporting the location of distress signals. The space-based portion of the system is not a satellite but an electronic package carried as a secondary payload aboard an operational satellite. The equipment acquires emergency signals and relays the information to search and rescue stations around the world.

Participants in this system include French and Canadian agencies, the U.S. Air Force, the U.S. Coast Guard, the National Oceanic and Atmospheric Administration (NOAA), and NASA, which operates a system called SARSAT, the monitoring element aboard NOAA weather/environmental satellites. The U.S.S.R. has developed a similar monitoring package compatible with SARSAT. There are nine ground listening posts called Local User Terminals (LUT's) located in the U.S.S.R., the United States, France, Canada, Norway, and England. When the monitor picks up an alert, it relays the information to an LUT and, within minutes, the LUT's computer produces a position fix for the distressed craft. The LUT notifies a search and rescue center that an emergency has occurred and gives the location of the craft.

Suitcase Communicator

A portable communication system was developed to relay messages over long distances by satellite when disasters such as earthquakes, hurricanes, or other emergencies prevent the use of other means of communication. The system consists of a collapsible antenna and a computerized terminal for sending and receiving messages. The communicator fits into two Pullman-size suitcases and can be powered from a conventional outlet or a vehicle's battery. An operator types a message on a keyboard of the terminal and transmits it to receiving stations by punching a single key. Reception of messages stored at the stations is enabled by punching another key. The terminal can be set up in 2 minutes. The antenna is unfolded and pointed toward the satellite, the direction and elevation of which are available from a simple chart.

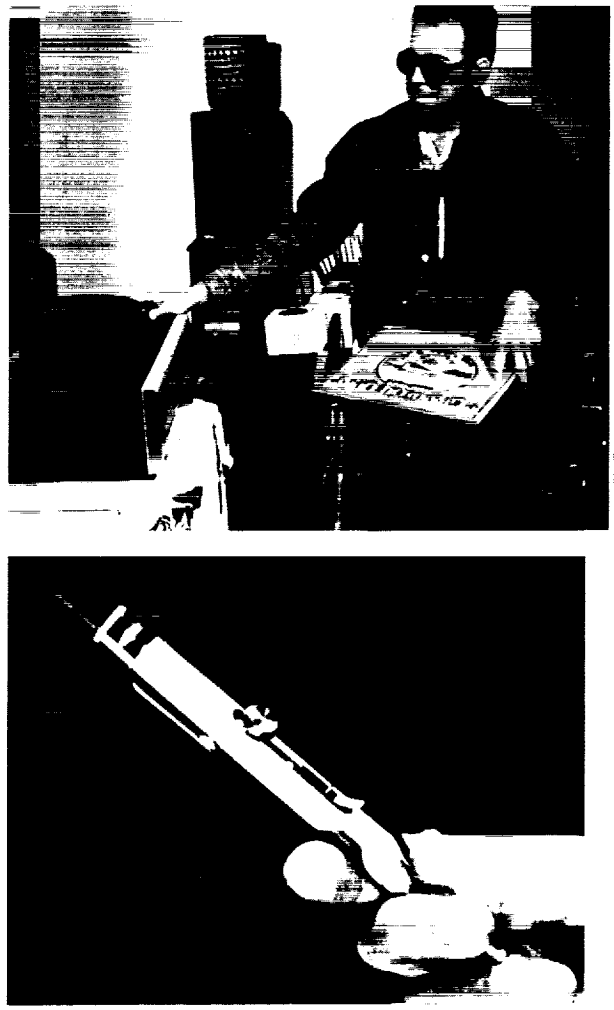


Suitcase communicator.

Silent Communications Alarm Network (SCAN)

The SCAN is a personal security system for summoning aid in emergencies. Its principal elements are a pen-shaped signaling device - "silent" because its ultrasonic alert signal is inaudible to the human ear - and a system of receivers interconnected with a constantly monitored master console. The SCAN pen, which weighs only 2 ounces, is worn on a necklace or attached by a clip to the user's clothing. The person in trouble simply presses a clasp, releasing a hammer inside the pen which strikes an aluminum bar. The impact causes the bar to resonate like a tuning fork and emit the ultrasonic signal, which is detected by the nearest of many small receivers mounted in apartments, corridors, stairwells, elevators, and carports. When the alert is transmitted to a master console, an audible alarm is produced and a console light that indicates the location of the emergency is activated.

The SCAN has been used in apartment complexes for handicapped and elderly tenants, schools, juvenile homes, correctional institutions, courthouses, hospitals, industrial facilities, and public buildings. It offers peace of mind and comforting assurance that, should an emergency arise, a simple press of the pen clasp will bring assistance.



Silent Communications Alarm Network.

Visual Alert System

A multipurpose security device for home and office use combines visual and audible alerts. It serves as a burglar alarm, a smoke alarm, and a door or telephone alert for the hearing-impaired. The system consists of an audio transponder and a companion receiver attached to a door, a window, or a telephone. The transponder detects vibrations caused by a knock on the door, a break-in attempt, the opening of a window, or a ringing telephone. The vibrations are converted into a loud beeping tone, which is transmitted to the receiver plugged into an electrical outlet. The receiver switches on a lamp or causes it to flash. The receiver also detects sounds made by smoke

alarms and provides a visual alert. The system is designed to deter intruders by the loud beeping noise and to serve as an economical and reliable visual signaling device for those unable to hear sonic alerts.

Visual Alert System.

IMAGING AND SCANNING TECHNIQUES

Techniques have been developed by NASA to enhance images of the Earth, the Moon, and planets encountered on space probe missions. Computerized processing provides detail of planet surfaces acquired from sensitive detectors onboard unmanned spacecraft or satellites which pick up radiation (light, heat, or x-rays) emanating from planets, galaxies, or black holes. To acquire greater detail of planets, a multispectral scanner creates digital data by using a combination of radiation detectors, a mirror, and a telescope. The light and heat waves reflected from the surface of the planet strike the mirror, which bounces the light waves into a bank of detectors. The waves are separated into four spectral bands initially, and further separated into 64 levels of brightness. This information is converted into electronic signals sent to Earth, where a computerized signal-deciphering system translates the flow of data into images on photographic film. The images can be processed by a computer to correct sensor errors, to heighten contrast for feature emphasis, or to distinguish objects not visible to the human eye or to conventional cameras.

Optical scanning techniques were used on the Viking spacecraft camera system to analyze the surface of Mars. An optical profilometer was developed to obtain three-dimensional photographs showing the height and the depth of a planetary feature as well as its length and width.

Computerized image enhancement developed by NASA has resulted in spinoffs in the medical field for making x-ray technology more accurate for examining soft tissues and for developing a data bank of cardiovascular images which is used to treat patients with heart disease. Optical and infrared scanning technologies were used in developing instruments to help the blind to read and to identify denominations of paper money.

IMAGING TECHNIQUES

Cardiovascular Data Bank

A data bank of cardiovascular patients' histories documents clinical experience of more than 4000 patients and is used as an aid to diagnosis and treatment of new patients with heart disease. Data are stored in a computerized system which allows a physician to summon detailed records of former patients whose medical profiles are similar to those of a new patient. A video display shows prognostic information for the new patient based on similar past experience. Image processing techniques developed by the Jet Propulsion Laboratory were used to solve problems associated with developing an input mechanism for graphic data and to establish a data storage system capable of using the accumulated information to develop prognoses.

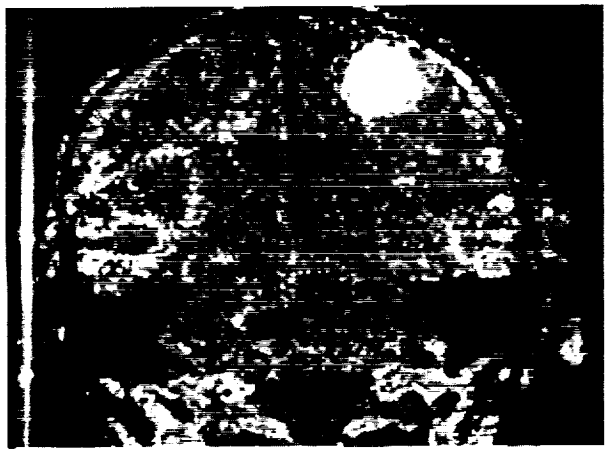
Cardiovascular data bank.

Nuclear Magnetic Resonance Imaging

Nuclear magnetic resonance (NMR) is a technique for viewing the inner parts of the human body without surgery. It uses a magnetic field and radio waves to create body images from which radiologists can extract diagnostic information. It is noninvasive and can penetrate bone, which normally blocks x-rays. A vast amount of anatomical and physiological information can be acquired, but the NMR scanner collects a great amount of redundant data making interpretation difficult. The NASA Landsat computerized image processing technology was used to make "theme maps" of the human body. A computer program searches the NMR image for a signature of interest to the radiologist, such as a blood clot in the brain, and colors any area that has that

particular signature. These theme maps show a precise demarcation between the affected area and parts of the body which are unaffected and thus facilitate earlier diagnosis of many disorders.

Other image-enhancement spinoffs include a Medical Image Analysis Facility which was created to use enhancement techniques for analyzing x-ray films of internal organs such as heart and lungs. The facility offers a faster method of studying the effects of complex coronary lesions in humans. Further refinement of x-ray images is accomplished by using filters, developed by NASA for Landsat, which block out the bone to display soft tissue. An Ocular Screening System uses NASA's image processing technology to evaluate a flash of light reflected from the retina of the eye back to the camera lens and onto color film. Unusual appearance of the pupils may indicate the presence of eye defects.



Nuclear magnetic resonance imaging.

SCANNING TECHNIQUES

Micro-Dose X-ray System

NASA's experience in detecting and processing cosmic x-rays resulted in development of a Micro-Dose X-ray System which employs advanced scanning beam technology. It provides high-quality images at extremely low radiation doses. A digital radiography system was developed for medical diagnosis. A patient is scanned by equipment while a physician monitors the result on a video screen. Using computerized data from a single x-ray exposure of a patient, the physician can vary the image electronically to concentrate on some muscle or soft tissue while simultaneously varying the amount of contrast. The exceptional image clarity and extremely low radiation dosage of the system enables use of digital radiography in applications often considered impracticable such as pediatrics and obstetrics.

Micro-Dose X-ray System.

Optical Profilometer

Surgeons specializing in cleft palate surgery make repeated casts of the palate, initially in infancy and later at various stages of treatment. Each cast is measured visually and photographically. By comparing successive casts, the surgical team notes the changes which have resulted both from surgery and from the patient's normal growth. Cast analyses are progress reports which provide information for determining the next surgical steps. The optical profilometer electronically "reads" the contours of the cast and obtains exact measurements by detecting minute differences in the intensity of a light beam reflected off the cast. The information is computer processed and delivered to the surgical team as a printed readout, which amounts to a mathematical, three-dimensional "relief map" of the palate cast.

Optical Profilometer.

Paper Money Identifier

The Paper Money Identifier is a device for enabling the blind to identify the denominations of paper money. Although not distinguishable by the human eye, each denomination of U.S. currency has a unique distribution of colors. The device, the size of a cigarette pack, emits a narrow beam of invisible infrared light. This beam reacts to the reflectivity of the colors on the bill and causes an oscillator to generate an audible signal. A distinctive series of tones identifies each denomination. The device allows blind people to handle paper money in places of employment which may not have been possible before.

Paper Money Identifier.

Optacon

The Optacon permits the blind to read almost anything in print. The Optacon gets its name from optical-to-tactile converter and is based on optical and electronic technology developed for NASA. It works by converting regular inkprint into a readable, vibrating tactile form. The blind

reader moves a miniature camera across a line of print with one hand while the index finger of the other hand is placed on the system's tactile array. As the camera moves over a letter, the image is simultaneously produced on a tactile array by small vibrating rods. The reading finger feels the enlarged letter as it passes over the tactile screen. After considerable practice, speeds of 40 words per minute are common and speeds as high as 90 words per minute have been achieved.

Optacon.

EQUIPMENT AND INSTRUMENTATION

During the evolution of the U.S. space program, it was necessary to develop new technology to prepare for astronauts working in the space environment. One of the greatest achievements of the space program has been the miniaturization of solid-state circuitry electronics and equipment to reduce the complex logistics of space operations and to meet stringent weight and power requirements. Existing medical electronics, life support, and air sampling and analysis equipment were reduced in size for use in spacecraft.

Subminiaturized pressurization systems and small attitude control valves for satellites were developed by NASA. "Peanut" valves, named for their small size, were a part of the experiment packages on the Viking spacecraft. They were used to measure the nutrients in the martian soil samples in precisely controlled amounts to investigate the possibility of life on Mars. Teleoperators were commanded to obtain soil and atmosphere samples, to analyze them automatically, and to send the findings back to Earth. New or modified biochemical equipment was developed for analyzing the body fluids and respiratory gases of the astronauts during medical experiments.

Training devices for astronauts were developed to simulate the 1/6g on the lunar surface and to simulate flight operations in the spacecraft. Technology was developed for a self-contained lunar drill which was lightweight, compact, and independently powered. The drill was used in extracting core samples from beneath the Moon's surface.

Medical science has benefited from NASA technology with the development of diagnostic, treatment, and biochemical analysis equipment. Bones may be examined for fractures or for deterioration, or may be operated on with cordless surgical instruments. Seven-minute physical examinations can be performed, blood pressure controls analyzed, and eye defects determined using equipment developed as a NASA spinoff. Equipment for medical treatment includes cardiac pacemakers, a plasma filtration system, a prosthetic urinary sphincter, and wheelchairs with computer-controlled equipment to replace lost functions of the handicapped. Analyzers for detecting bacteria or determining blood constituents and unique training devices are also spinoffs from NASA technology.

MEDICAL DIAGNOSIS

Lixiscope

The Lixiscope is a self-contained, battery-powered fluoroscope which produces an instant x-ray image through use of a small amount of radioactive isotope. It is designed to use less than 1 percent of the radiation required by conventional x-ray devices. The hand-held unit's portability allows its emergency use in field situations in which immediate fluoroscopic examination is indicated; for example, scanning for possible bone injuries to athletes. The Lixiscope's small size and low radiation dosage also make it attractive for applications such as emergency room examination of small children.

Lixiscope.

Bone Stiffness Analyzer

A practical, inexpensive, noninvasive means of making quantitative measurements of bone stiffness and mass to determine the occurrence of bone deterioration induced by astronaut inactivity under weightless conditions was sought by NASA. A system had to be sufficiently sensitive to monitor and evaluate small changes. The Bone Stiffness Analyzer is a computer-controlled impedance-probe system in which bone stiffness is determined quantitatively by measuring responses to an electromagnetic shaker. The shaker applies vibration and the probe measures the resulting impedance (electrical resistance) providing a basis for computer analysis and determination of bone stiffness. Since bone deterioration affects a substantial portion of the U.S. population, the Bone Stiffness Analyzer also meets a need in hospitals, clinics, and convalescent homes as a tool for diagnosis of bone abnormalities caused by disease, aging, and disuse, and as a means of evaluating fracture healing.

Bone Stiffness Analyzer.

Auto-Refractor

An infrared optometer which measures the eye's ability to focus was created by Stanford Research Institute under a grant from NASA to measure the visual performance of pilots and astronauts. Based on this technology, an Auto-Refractor was developed which automatically measures the refractive error of the eye, detects cataracts if present, and prints out the proper prescription for glasses. A special-purpose computer provides a readout, or prescription, in three values: sphere error that measures farsightedness and nearsightedness, cylindrical error, and cylindrical axis. The last two measure the degree of astigmatism. Performance of these measurements requires less than 4 seconds.

The Auto-Lensmeter is a companion instrument to the Auto-Refractor. It is an automated optician's aid which measures the corrective prescription ground into eyeglasses and contact lenses in a fraction of the time normally required. The lens is positioned on a mount, the operator presses a button, and, in 2 seconds, the results appear in standard prescription form, on a digital display, or on a printed record.

Auto-Refractor.

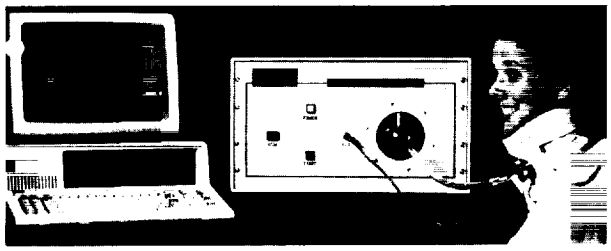
Medical Data Acquisition Unit

The Medical Data Acquisition Unit enables performance of a 7-minute physical examination without the patient disrobing or needing a physician. The unit records weight and measurements in 7 seconds. A blood pressure cuff contains a microphone which detects pressure sounds and reports them to a console for translation into blood pressure readings. The unit also includes an automatic electrocardiogram. The console records all data for later analysis.

Medical Data Acquisition Unit.

Baro-Cuff

The Baro-Cuff is a silicone rubber chamber strapped to the neck of a patient which stimulates the blood pressure controls in the carotid arteries by electronically controlled application of pressure or suction. The Baro-Cuff can be used to study blood pressure controls in patients with abnormal controls such as those with congestive heart failure or chronic diabetes mellitus.



Baro-Cuff.

Several other spinoffs have been developed in the medical diagnostic field. These include a transducer which can determine the flexibility of arteries externally; a blood vessel tension tester which is a laboratory apparatus used to study the reaction of vascular smooth muscles to stimulants such as coffee, tea, alcohol, or drugs; automated blood pressure measurement devices; heart rate monitors; and a device for identifying disabling lung diseases in early stages.

MEDICAL TREATMENT

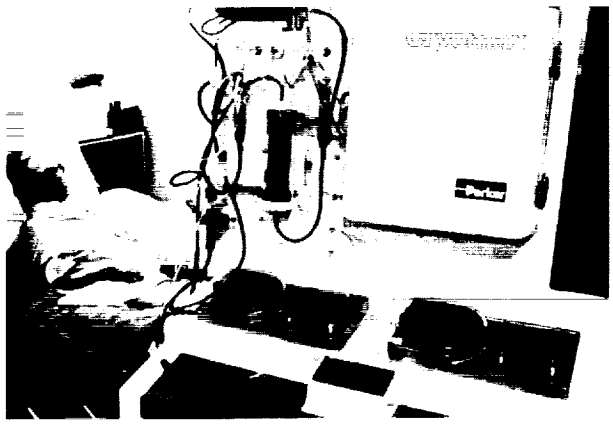
Cardiac Pacemaker

When the natural heartbeat becomes irregular because of heart disease, an implanted electronic pacemaker delivers small, regular electric shocks to pace the heart. The pacer's nickel-cadmium battery can be recharged through the skin by inductance in 90 minutes eliminating the recurring need for surgery to implant a new battery. The pacer weighs 2 ounces and has a lifetime of 10 to 20 years. The device is immune to electrical interference such as that produced by microwave ovens or automotive ignitions, which sometimes stop conventional pacemakers.

Cardiac pacemaker.

Cryomax

Based on fluid handling expertise acquired in developing many systems for NASA, a drugless therapy system called Cryomax was created for treatment of such disorders as rheumatoid arthritis and lupus. The plasma filtration system removes certain substances from the blood which are believed to contribute to progression of these diseases.



Cryomax.

Cordless Surgical Instruments

An orthopedic instrument line developed from NASA technology includes a drill for boring through bone, a driver/reamer used for heavy-duty bone shaping, and a sagittal saw for cutting bone without damaging tissue. All provide as many as 20 minutes of powered operation on a single charge, which is more than enough for most orthopedic procedures. The powerpack is the instrument's handle, which can be removed for recharging. A companion microprocessor-controlled recharging unit can recharge two powerpacks simultaneously in 30 minutes. The instruments can be gas-sterilized, steam-sterilized in an autoclave, or immersed for easy cleaning. The instruments need no connection to a power source such as those requiring tanks with connecting lines or hoses which must be sterilized and may tangle or burst. The lunar drill technology was also used to develop household equipment such as a miniature hand-held vacuum cleaner, cordless drills, shrub trimmers, and grass shears.

The NASA Lewis Research Center developed a battery-powered eye surgery light that can deliver high-intensity light for close examination of the retina of the eye. The ophthalmoscope powerpack consists of eight batteries in three containers affixed to a webbed belt and an on-off switch equipped with a spring-loaded plexiglass "flapper." The belt pack is worn underneath the surgical gown, and the flapper permits the doctor to activate the switch by elbow pressure. The system totally frees the surgeon of electric power cords, attached to an overhead swivel arm or to a floor pedestal, which may become tangled when more than one ophthalmoscope is required during surgery.

Cordless surgical drill.

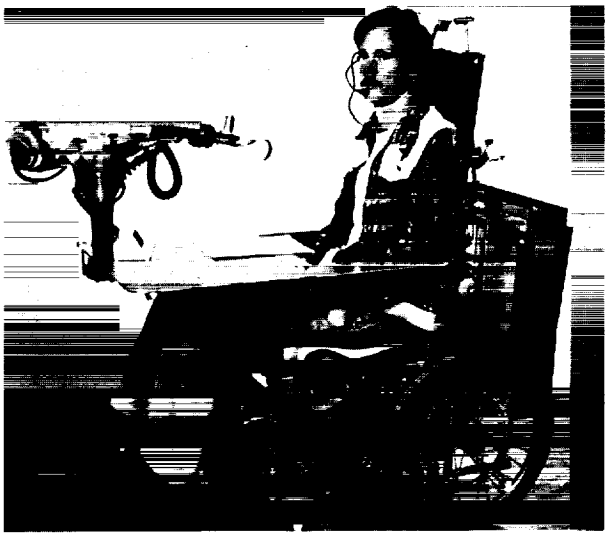
Voice-Controlled Wheelchair and Manipulator

The voice-controlled manipulator on a wheelchair can pick up packages, open doors, turn a TV knob, and perform a variety of other functions for handicapped people. The system responds to 35 one-word commands, such as "go," "stop," "up," "down," "right," "left," "forward," and "backward."

The heart of the system is a voice-command analyzer which uses a minicomputer. Commands are taught to the computer by the patient's repeating them a number of times. Thereafter, the analyzer recognizes commands only in the patient's particular speech pattern. The computer translates commands into electrical signals, which activate appropriate motors and cause the desired motion of chair or manipulator.

A related device is a Versatile Portable Speech Prothesis system for those who have lost their speech because of stroke, cerebral palsy, muscular dystrophy, Parkinson's disease, or multiple sclerosis. The system is mounted on a wheelchair and includes a word processor, a video screen, a voice synthesizer, and a computer program by which the synthesizer is instructed to produce intelligible sounds in response to user commands. The memory can store several thousand words of the user's choice. Depending on the user's

disability, messages are selected by operating a simple switch, a joystick, or a keyboard. When the message appears on the video screen, the user activates the speech synthesizer, which generates the sounds for the words.



Voice-controlled wheelchair and manipulator.

Pneumatically Operated Mitt

The Pneumatically Operated Mitt is a therapeutic aid for rehabilitating the fingers of paralyzed, arthritic, or severely burned hands. Air pressure in the mitt opens and closes the hands to prevent rigidity of the immobilized muscles. The patient conducts his own therapy and can stop the pain whenever he wishes by turning off the machine. The device frees therapists for other work, and the psychological effect of the patient control has resulted in reducing by one-half the overall therapy time.

Additional spinoffs include a prosthetic urinary sphincter for those suffering from severe urinary incontinence and an autocuer, which is a lipreading aid consisting of a battery-powered miniaturized microcomputer system the size of a cigarette pack and an eyeglass display unit.

Pneumatically Operated Mitt.

BIOCHEMICAL ANALYSIS

Gas Analyzers

The Remote Monitoring System (RMS) is a gas analyzer used in hospital operating rooms to monitor the use of anesthetic gases and to measure oxygen, carbon dioxide, and nitrogen concentrations. The RMS assures that a patient undergoing surgery has the proper breathing environment. The system can monitor as many as 16 patients with displays of 6 gases at a central station and within each operating room. The RMS provides an alarm if the concentrations of gases are too high or too low. The heart of the system is a fully automatic gas analyzer developed to monitor astronauts' respiratory gases to document changes in cardiopulmonary status resulting from space flight.

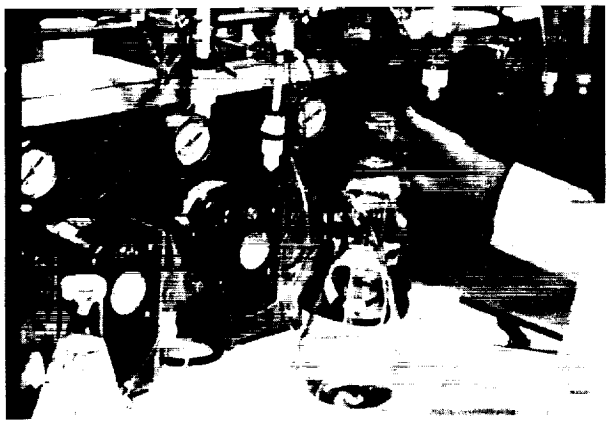
Remote Monitoring System.

The Michromonitor 500 is a portable, battery-powered gas analyzer which has a sensing wand connected to a computerized analyzer for measuring gas concentrations as small as 1 part per million for some gases and 10 parts per million for other gases. A pushbutton keyboard allows selection of as many as 10 gases at a time for analysis. The system is programmed to identify as many as 100 different gases. Only 45 seconds are required to complete a measurement cycle and, at the touch of a button, the results of each analysis such as the identity of gas, its concentration, and the time of analysis appear in a display window. This analyzer has a wide range of applications such as industrial safety, monitoring work areas for gas leaks or volatile chemical spills, analyzing industrial process gases, monitoring stack gases for compliance with pollution laws, identifying gases produced during energy explorations; in police work, breath alcohol analysis and arson investigations; and in medicine, respiratory and anesthetic analysis.

Michromonitor 500.

Medical Diagnostic Assays

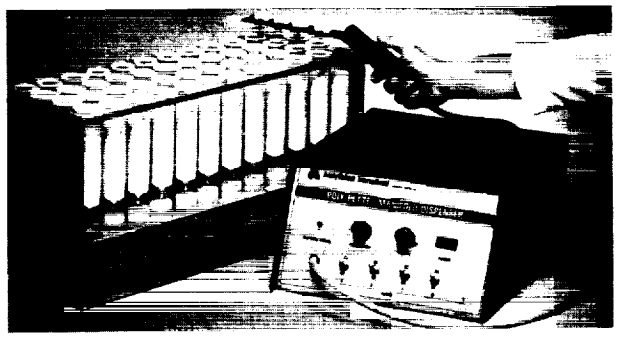
A line of medical diagnostic assays was developed on the basis of biochemical technology information search and retrieval service provided by NASA's New England Research Application Center (NERAC). The assays are used for testing blood samples and other biological fluids, analyzing a patient's body fluids compared with normal values, and aiding physicians in confirming or otherwise diagnosing a suspected disease condition. The NERAC rapid information retrieval has proved invaluable in expanding new technology and has permitted large-scale savings.



Medical diagnostic assays.

Extube

Liquid/liquid extraction is a term used in chemistry to describe a method of separating chemical compounds contained in blood, urine, or other biological fluids. Extube is a disposable extraction column which was developed as an improved and easier way to extract compounds from liquids. A body fluid sample is poured into an Extube filled with an inert, water-absorbent granular material. This material absorbs water and impurities from the sample and spreads the specimen as a very thin film over a large area. To extract a particular compound, an appropriate liquid solvent is introduced into the tube. As the solvent passes through the filling material, the desired compound becomes dissolved in the solvent and exits through the tube's nozzle. A different compound may be extracted from the remaining sample by introducing another solvent.

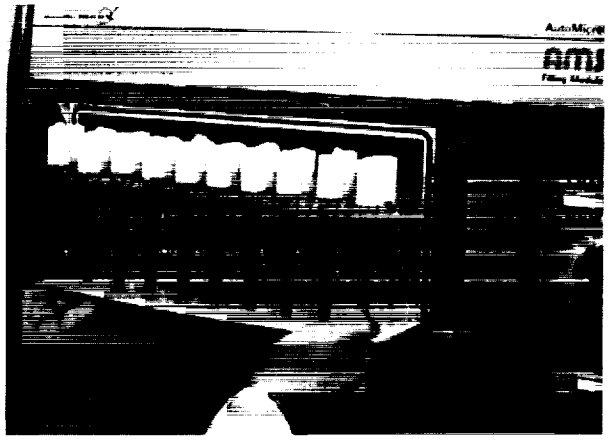


Extube.

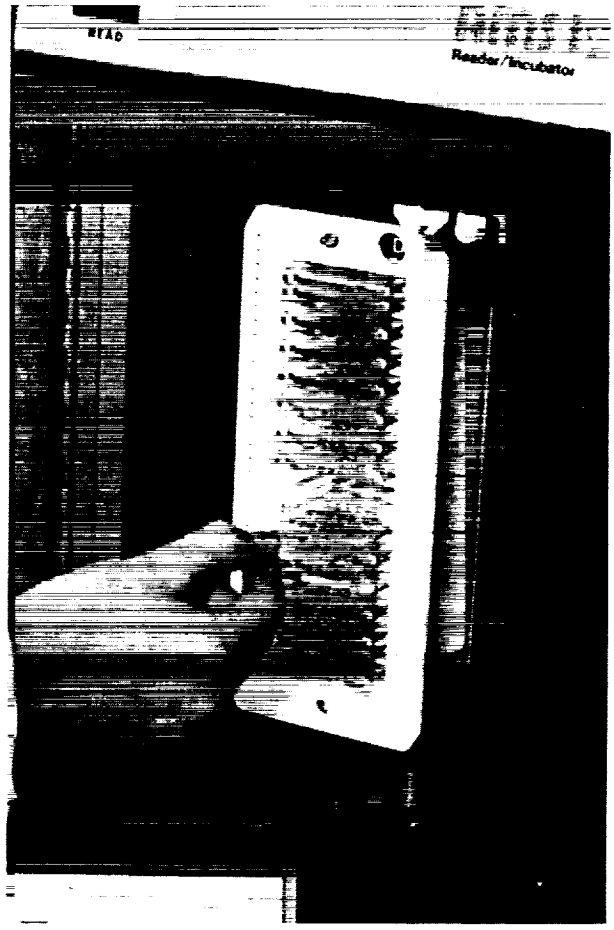
The original development by NASA was undertaken as an aid to the Los Angeles Police Department allowing more rapid detection of drugs in biological samples as part of the department's drug abuse program. The one-step technique sharply cuts processing time, reduces costs, and eliminates much of the equipment requirements. An automated system for analyzing the extracted compounds which is called Automated Drug Identification (AUDRI) also has been developed. This device combines computer, spectrographic, and gas chromatograph technology for drug identification.

AutoMicrobic System

The NASA developed technology to detect the presence of harmful micro-organisms in the body fluids of astronauts. As a result of this technology, the AutoMicrobic System (AMS) was developed to identify and analyze these micro-organisms. The system automatically prepares, incubates, and analyzes cultures and reports the presence and identity of pathogens, or harmful organisms. A third-generation system in current use performs the functions much faster than the original system.



AutoMicrobic System.



AutoMicrobic System.

Instead of the petri dishes customarily used to incubate cultures from body fluids, the AMS uses disposable test kits. The test kits are plastic cards, approximately the size of playing cards, which have 16 to 30 wells containing different chemical substances. The two types of cards used by the system are identification cards and susceptibility cards. The body fluid sample is injected into the identification card, and organisms react with the chemicals in the wells. Cards are placed in an incubator/reader, which scans activity once each hour, "reads" the reactions, compares them with identification in the computer, and identifies the organism. In the susceptibility card, wells contain different antibiotics. The organism is injected into these wells for computer determination of the antibiotic most effective in treating the organism. The complete process takes from 4 to 13 hours compared with 2 to 4 days for culture preparation. The AMS can handle as many as 240 specimens at a time.

ATP Photometer

The ATP Photometer is an instrument which was developed to make a rapid and accurate count of the bacteria in a body fluid sample. It is based on NASA technology developed for life detection missions to Mars. The photometer provides information on the presence and quantity of bacteria by measuring the amount of light emitted by the reaction between two substances. The substances are adenosine triphosphate (ATP), which is present in all living cells, and luciferase, an enzyme derived from fireflies which releases light only in the presence of ATP. These reactants are applied to a human body sample such as urine, blood, or spinal fluid. The photometer observes the intensity of the light output and displays its findings in a numerical readout. Total assay time is usually less than 10 minutes.

In addition to medical applications, the ATP Photometer has been successfully employed for such other uses as measuring organisms in fresh and ocean waters, determining bacteria contamination of foodstuffs, and, in the beverage industry, for biological process control.

ATP Photometer.

Electrophoresis System

Electrophoresis is a process whereby the components of a fluid are separated by electric current. In the mid-sixties, the NASA Ames Research Center sponsored development of an automated electrophoresis device which would work in a weightless environment to provide information on blood behavior under zero-g conditions. Although the device was not flown in space, the technology was used to develop a new advanced system. The resulting system is a versatile, economical assembly for rapid separation of specific blood proteins in very small quantities to enable subsequent identification and quantification. The system is capable of handling 10 to 20 samples simultaneously. The system is both a research instrument and a diagnostic aid, with many applications in medicine, law enforcement, pathology, biochemistry, and other biological sciences. As a system for analyzing substances other than blood, it offers applications in the food, agriculture, cosmetic, and pharmaceutical industries.

Blood Cell Freezing System

Drugs and radiation used to destroy cancerous cells during leukemia treatment eventually also destroy the bone marrow which produces disease-fighting white blood cells. Previous attempts to develop an adequate freezing system either destroyed the cells by rupture when cooled too quickly or by dehydration when cooled too slowly. A freezing unit developed by the NASA Goddard Space Flight Center monitors the temperature of the cells. A thermocouple placed against a polyethylene container relays temperature signals to an electronic system, which in turn controls small heaters located outside the container. The heaters allow liquid nitrogen to circulate at a constant temperature and maintain consistent freezing rate. White blood cells and bone marrow can be stored for future use by leukemia patients when this freezing system is used.

TRAINING DEVICES

Weight Alleviation Device

The lunar gravity simulator which was built to acquire biological and metabolic data of astronauts while training for walking on the Moon has been adapted to enable a person to walk and relearn muscular coordination following a stroke. It also is used to assist in rehabilitation exercises for physically and mentally incapacitated children. Individuals who are incapable of supporting their entire weight with their legs also have used this device to prevent muscular atrophy.

Weight alleviation device.

Skiing Simulation

The use of a wind tunnel used for NASA research was donated for a program aimed at improving the performance of the members of the U.S. Ski Team by determining the optimum aerodynamic body positions at varying speeds in either ski jumping or downhill racing. A computer program simulates the conditions of actual ski courses, instruments measure and display lift and drag values, and video screens show a skier how changes in body position affect lift and drag. Initiated in 1979, wind-tunnel simulations have become an annual part of the U.S. Ski Team's training for U.S. and international events.

Skiing simulation.

Other Devices

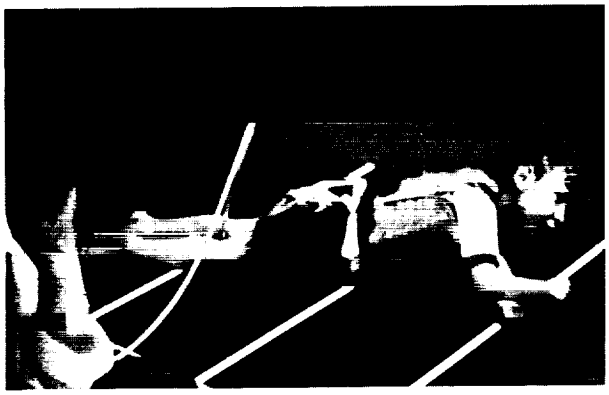
Other training devices developed from NASA technology include isokinetic lightweight exercise equipment originally designed to reduce cardiovascular and musculoskeletal deconditioning resulting from weightlessness; a cardiology electronic mannequin simulating 40 heart disease conditions for training medical students; and an ambulance handbook which provides a checklist of procedures for diagnosis, treatment, and stabilization of a wide variety of emergencies.

Vehicle for Initial Crawling

Some brain-injured children are unable to crawl because of problems of weight bearing and friction caused by gravity. The Institutes for Achievement of Human Potential sought a

method of reducing the gravity for several years. Through a collaborative effort with the NASA Ames Research Center, an effective crawling aid was created based on NASA technology developed for frictionless systems which were designed to simulate the motions of satellites in space.

The vehicle is a rounded plywood frame large enough to support the child's torso, leaving arms and legs free to move. On its underside are three aluminum disks through which air is pumped creating an air-bearing surface that has less friction than a film of oil. The upper side contains the connection to the air supply and a pair of straps which restrain the child and cause the device to move with him. With repetitive use of the device, the child develops arm and leg muscles as well as coordination.



Vehicle for initial crawling.

Firefighting Trainer

A prototype simulator known as the Emergency Management Computer-Aided Training (EMCAT) system was developed, based on NASA flight simulator technology, to train firefighters. The simulator enables a trainee to assume the role of ground commander and make quick decisions on the best use of his firefighting personnel and equipment. A video tape is played on a TV monitor showing firefighting situations requiring that decisions be made. On a keyboard, the firefighter taps out decisions which cause the fire to be extinguished or to go out of control. At the end of the exercise, the firefighter is critiqued by an instructor and informed as to which decisions were right or wrong.

Firefighting trainer.

MATERIALS

Great advances in the development and possible uses of materials have come from NASA's research and development programs. The design and composition of spacesuits for astronauts which must protect them from cosmic radiation, temperature extremes, and potential fire hazards while providing flexibility and mobility created the need for developing many new fabrics.

Composite materials were developed for the space program when a need was recognized for lighter, more reliable, and durable materials which could easily be molded into complex structures. Composite materials are used by NASA for satellite structural subsystems; collapsible, stowaway spacecraft tanks; oxygen tanks; aircraft seats; and construction of helicopters and aircraft frames.

The development of special coatings was necessary to protect fuel tanks and fuel lines for aircraft in case of fires, to keep spacecraft windows and astronaut helmets from fogging, and to provide heat shielding for plastic surfaces of spacecraft equipment.

The process for creating materials which are coated with metal was supported by NASA research. The first time metallized materials were used in the space program was for the surface material of the Echo 1 communications satellite. The material selected was Mylar polyester coated with a reflective layer of tiny aluminum particles such that the satellite's skin had a thickness about half that of the cellophane on a cigarette package. Further space applications for metallized materials were mainly for thermal insulation and protection from cosmic radiation. Metallized film was used on every U S. spacecraft from early satellites through the manned Apollo and Skylab Programs.

Laminated layers of transparent plastic encased in a thin film of gold were developed for faceplates in helmets worn by U.S. Air Force pilots flying reconnaissance and weather research planes and by Apollo astronauts. The coating is electrically conductive and emits low-energy radiant heat.

COMPOSITE MATERIALS

Wheelchairs

A wheelchair designed for use on airplanes is capable of passage through narrow airline aisles to move passengers to their seats and give them access to lavatories. It is constructed from composite materials which are lightweight, stable, and durable. The chair weighs only 17 pounds, one-third the weight of a conventional wheelchair, can support a 200-pound person, and may be folded and stowed when not in use. More than 700 000 people in the United States rely on wheelchairs for mobility. Few of them travel by air because of the difficulties encountered at airports, in boarding airliners, and particularly with mobility in the airplane. This wheelchair will assist in extending the mobility during airline travel for those depending on wheelchairs.

Airline wheelchair.

Several wheelchair research projects sponsored by the Veterans Administration and the National Institute of Handicapped Research have resulted in development of an entirely new wheelchair based on aerospace technology. Aerospace computerized structural analysis techniques were used to arrive at an optimum design using composite materials. The resulting chair weighs only 25 pounds but has the same strength and weight-bearing capability as a 50-pound stainless steel wheelchair. It can be collapsed for automobile stowage and has a solid seat, dynamic brakes, shaped hard rims, and a footrest with smooth contours to aid in opening doors.

Equipment and Devices

A foldable walker was built for use by paraplegics to ascend and descend stairs. Paraplegics can use crutches on level ground, but crutches are ineffective on stairways. The walker is constructed of a graphite-epoxy composite which is stronger yet 50 percent lighter than aluminum. The front legs are 8 inches longer than the rear legs to provide a stable pair of rails to push against. The walker is light enough to carry while walking on crutches and is foldable so that it may be easily carried.

Foldable walker.

A protective face mask was developed to prevent head and facial injuries to people who have epilepsy or cerebral palsy. Physical impairment causes frequent falls while walking. A composite material of graphite or boron fibers was used to construct the mask, which weighs less than 3 ounces. The device prevents injuries and may be reconfigured for other users such as muscular dystrophy patients, football linemen, and riot control police.

Graphite- and boron-reinforced composite materials have been used by many companies to create sports equipment such as golf clubs, casting rods, javelins, and vaulting poles. The materials provide stiffness to the shafts of the equipment and reduce weight. Inexpensive prosthetic devices, such as joints, arms, and legs, developed from composite materials outlast their plastic counterparts.

Portable Dental System

A backpackable dental system, which includes a patient's chair, a dentist's stool, an x-ray machine, a power unit, and a collapsible compressed-air tank, was developed. The outer skin of the tank is made of aramid fibers which are woven in flexible resin and wound around an inflated bladder that serves as an inner tube. The toughness and abrasion resistance of the composite fibers protect against punctures and ensure leak-free operation.The portable system provides dental care to isolated communities and is being evaluated for field dentistry by the U.S. Armed Forces.

Portable dental system.

Oxygen Bottles

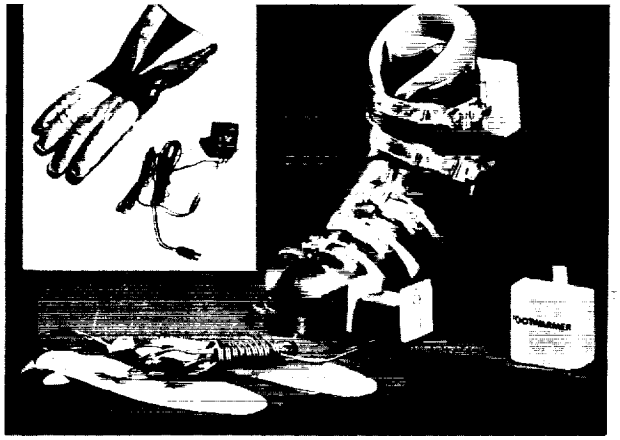
Oxygen bottles containing twice as much oxygen and weighing almost 20 percent less than previously used steel cylinders were derived from NASA rocket-propellant tank technology and composite materials development. They were developed for use by astronauts during EVA or while on the Moon as part of the portable life support system. The bottles are aluminum cylinders overwrapped with reinforcing Kevlar aramid filaments. Kevlar is a fiber that, pound for pound, is five times stronger than steel. Each bottle is wrapped with 1670 miles of filament three times finer than human hair. This construction reduces weight and provides a stronger bottle. The extra strength enables containment of higher air pressure and thus accommodation of more oxygen in the same volume.

The bottles are used for firefighter's air tanks and as breathing equipment for scuba divers During the American Bicentennial Mount Everest Expedition, 200 bottles were used by the mountain climbers. The weight and air volume advantages reduced the number of cylinders needed and reduced the overall breathing system weight requirement by about one-half.

Firefighter's air tanks.

Oxygen bottles.

Thermal boots and gloves are insulated with material developed for the space boots of astronauts. Batteries worn inside the wrist of the glove or sealed in the sole of a ski boot are rechargeable hundreds of times. They operate a variable-resistance circuit which is turned on periodically when the wearer wants to be warmer. Unheated thermal gloves would be adequate as long as the insulation stays dry. Moisture from without or from perspiration saturates conventional insulation materials. A monofilament, open-mesh material developed for NASA "wicks away" the moisture.



Thermal boots and gloves.

Temper Foam

Temper Foam is an open-cell polyurethane silicone which has great shock-absorbing capacity. It takes the shape of impressed objects but returns to its original shape even after 90 percent compression. It is temperature sensitive, becoming softer when warm and firmer when cool. Temper Foam has been used for the construction of football pads, helmet liners, baseball chest protectors, soccer shinguards, x-ray table pads, hospital bedpads, wheelchair seats, off-road vehicle seats, and ski boots.

Temper Foam.

COATINGS

Anti-Fog Coating

An anti-fog compound was developed by NASA to prevent fogging of astronauts' helmet visors and spacecraft windows. The basic composition includes a liquid detergent, deionized water, and an oxygen-compatible, fire-resistant oil. The variety of applications includes fog prevention for eyeglasses, ski goggles, skin-diving masks, car windows, bathroom mirrors, camera lenses, and helmet face shields worn by firefighters or motorcyclists.

Anti-fog coating.

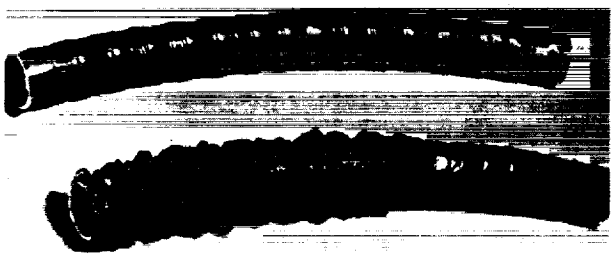
Scratch-Resistant Coating

In 1972, the Food and Drug Administration issued a regulation that all sunglasses and prescription lenses had to be shatter resistant. Since that time, the use of plastic lenses has increased dramatically. Plastic lenses are lighter, can be shaped in various forms, and have better absorption of ultraviolet rays than do glass lenses. However, many types of plastic lenses develop scratches which reduce visibility. A highly abrasion-resistant coating developed by NASA to protect plastic surfaces of aerospace equipment was used to create a line of sunglasses that has five times better scratch resistance than the most popular corrective lenses.

Scratch-resistant coating.

Coatings for Fuel Lines

One of the main hazards of gasoline-fueled pleasure boats is fire or explosion. The application of tapes and coatings of fire-resistant materials to fuel hoses on inboard pleasure boats and to the interior of fiberglass hulls reduces this danger. The coating contains dispersions of nitro-amino-aromatic compounds which decompose and swell to as much as 200 times the original thickness. The coating releases gases and water which help quench fires. The low-density foam that remains provides insulation and forms a char that can reradiate heat.



Coated fuel lines.

FLAME-RESISTANT MATERIALS

Durette Fabric

Durette, a chemically treated fabric which will not burn or produce noxious fumes, is used for protective fire-retarding clothing. Firefighters' suits have been made from Durette, and several leading race car drivers wear Durette coveralls as protection against the possibility of fire. Sheets, patients' gowns, and attendants' uniforms are made from Durette for use in high-oxygen-pressure chambers and undersea medical clinics which have an increased risk of fire.

Durette fabric.

Beta Glass for Fire Entry Suits

Firefighters wearing suits made of Beta Glass can move directly into flames, a maneuver which is frequently required in combating fires involving highly flammable products. In addition to firefighting, the suits may be worn in industrial jobs characterized by worker exposure to high heat and other hazards such as steam and hot liquids. Beta Fiber was created as a ultrafine glass fiber yarn. When coated with Teflon, it was used for astronauts' spacesuits and called Beta Glass. It is thin, light, and flexible, yet durable and fire resistant in high-oxygen environments. Beta decorative fabrics are used in numerous commercial and institutional buildings because of their inherent firesafe qualities as well as their esthetic appeal.

Beta Glass for fire entry suits.

Firefighters' Ensemble

The firefighting system is an ensemble constructed of lightweight fire-resistant and heat-protective materials which offers maximum protection and greater ease of movement. A built-in "vapor barrier" allows the body to breathe. This feature protects against excessive heat stress. Besides an outer garment, the system includes boots, gloves, helmet, and face shield.

Firefighters' ensemble.

METALLIZED PRODUCTS

Clothing and Outdoor Gear

Aluminized Mylar, originally developed to make the Echo satellite more reflective, to insulate cryogenic fluids, and to insulate and provide micrometeoroid protection in spacesuits, has been used to make sportsman's blankets and jackets, ski parkas, and sleeping bags. The technology of vacuum metallizing plastic films has improved and the process has been expanded to include metals other than aluminum such as gold, silver, copper, and zinc. The total metallized product line which is available includes scores of items from insulated outdoor garments to packaging materials for frozen foods, from wall coverings to aircraft covers, from bed warmers to window shades, from labels to candy wrappings, and from reflective blankets to photographic reflectors.

Gold-metallized jacket.

Thermos emergency blanket.

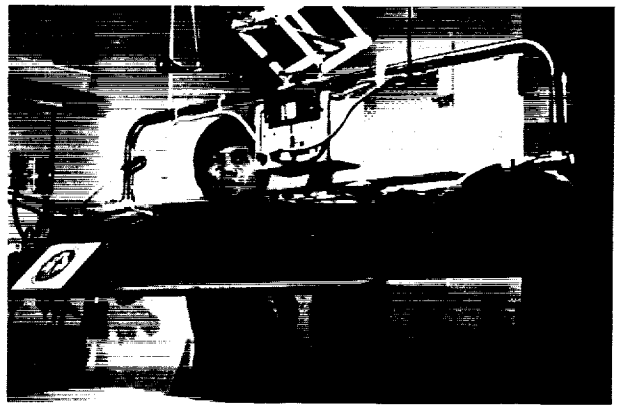
A blanket for sportsmen, weighing only 12 ounces, can be used equally well to keep heat away or to keep available heat in. A similar blanket used for emergency rescue is strong enough to be used as a litter, yet can be folded and carried in a shirt pocket. A gold-metallized jacket allows radar reflection, has high visibility under all light conditions, and is lightweight and waterproof. A reversible silver jacket, when worn with the silver side in, retains body heat. When

the silver is worn outside, it reflects the Sun's rays to keep the body cool.

All-weather blankets.

Radiant Warmer

The radiant warmer is a "golden canopy" which provides uniform controlled warmth to infants or to burn patients who cannot use sheets or blankets. The canopy is composed of laminated layers of transparent plastic which encase a thin film of gold. The film is electroconductive and, when energized by electricity, emits low-energy radiant heat over the patient's entire body



Apollo radiant warmer.

Ski Goggles

Ski goggles are defogged by applying radiant heat to the lenses to prevent moisture condensation. Electric heat is spread across the lenses by means of an invisible coating of electrically conductive metallic film. A small battery is built into the goggles' headband.

Defogging ski goggles.

Radar-Reflective Cover

Orange metallized-polyester film was developed by NASA to create a canopy for liferafts to assure that astronauts could be found if their returning spacecraft were off course during ocean landings. The canopy reflects radar signals to aid searchers in marine rescues and can be spotted by radar from 15 miles away. The covering material also has been used on life preservers. A man floating with a life preserver coated with the radar-reflective material can be sighted from an altitude of 6000 feet.

Radar-reflective cover.

SPECIAL TECHNOLOGIES

Several specialized technologies were developed by NASA to ensure the health and safety of the astronauts during flight, EVA, and recovery. These include processing, storing, and heating food supplies sufficient for 84 days for a three-man crew during the last Skylab mission; sterilization and quarantine techniques and procedures to prevent contamination of spacecraft equipment and lunar samples and to prevent preflight exposure of the astronauts to infectious diseases; development of liquid-cooled garments to maintain thermal equilibrium during EVA and during lunar excursions; provision of useful transportation during lunar exploration; development of solar energy for providing spacecraft power to create a habitable environment; and development of improved rafts for helicopter recovery of astronauts during ocean landings.

FOOD SYSTEMS

Meal System for the Elderly

Meals for spacecraft crews had to be tasty and nutritionally balanced, yet lightweight, compactly packaged, storable without refrigeration, and easy to prepare. New methods for compressing and freeze-drying foods were developed to meet NASA's physiological, operational, and engineering constraints.

Studies have shown that many elderly people do not eat adequately because of expense, because of limited mobility, or because of inconvenience. Meal System for the Elderly is a cooperative program in which NASA's food preparation expertise is used to improve the nutritional status of elderly people. The program seeks to fill a gap by supplying nutritionally balanced food packages to elderly people who are unable to participate in existing meal service programs.

Meal System for the Elderly uses a freeze-drying process in which water is extracted from freshly cooked foods by dehydration at very low temperatures, as low as 50° below zero. Flavor is locked in by packaging the dried food in pouches which block out moisture and oxygen, the principal causes of food deterioration. The food can be stored for long periods without refrigeration. Meals are reconstituted by adding hot or cold water, depending on the type of food, and they are ready to eat in 5 to 10 minutes. More than 21 menus are available. Easy Meal is an offshoot of Meal System for the Elderly. The meals also are beneficial to elderly people who live in rural areas and to people who are handicapped, temporarily ill, or homebound for other reasons.

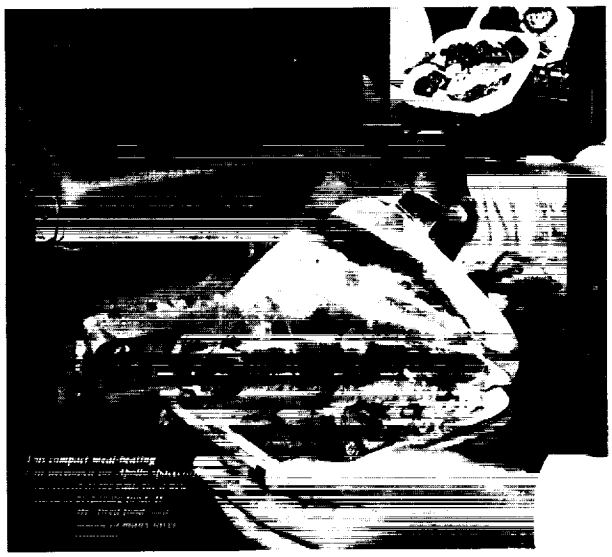
Meal System for the Elderly.

Electronic Food Warmer

A basic commercial design of a food heating unit intended for airline use was refined and improved to NASA specifications for use on spacecraft. A miniaturized control circuitry and energy conservation feature was added to meet the NASA reliability and low-energy requirements. This system is an entirely new concept of

electronic food warming. It uses no gas flame, no electric rods, no thermostats, and no radiation. Components of the system include a unique dish that serves as both plate and oven, and a roll-around control module that provides the heat source. Metal buttons on the shell of the dish-oven make electrical contact when they slide into the control module on conductor rails. A resistive coating on the bottom of the dish-oven converts electrical energy to heat. The device uses little electricity because the heat goes directly to the food and is not wasted by heating oven walls and surrounding air. Now in use in many hospitals and nursing homes, it provides a means of serving piping hot meals with better color and taste retention, no burning or drying out, and no loss of nutrition.

Electronic food warmer.



Electronic food warmer.

Ingestible Toothpaste

A new type of toothpaste which is foamless and can be swallowed after use was developed in response to NASA's concern in the 1960's about astronauts' oral hygiene. In a zero-g environment, the normal method of brushing teeth, with a lavatory for expectorating and a system for handling the expectorated waste, was not practical. The new toothpaste is used without water and is pleasantly flavored. The prime advantage in using the toothpaste is that it eliminates the possibility of choking on air bubbles, a problem among totally dependent patients. It also benefits bed-confined patients in hospital wards, paraplegics confined to wheelchairs, patients with oral-facial paralysis whose ability to expectorate is limited, the mentally handicapped, and others with disabilities that require attendants to brush their teeth.

STERILIZATION/CONTAMINATION CONTROL

Cleanroom Control Techniques

Sterile injectable drugs must be made as free of particulate matter, such as dust and pollen, as possible. High-efficiency particulate air (HEPA) filters have been used to remove 99.97 percent of all particles 0.3 micrometer diameter or larger As a part of the filter system, plastic curtains hang from the framework and direct the airflow. During low-humidity periods, static electricity buildup caused dust particles to cling to the curtains causing the potential of particulate contamination in the final product containers. Using the NASA Lyndon B. Johnson Space Center/Rockwell procedures which provide detailed information for reducing static electricity, guidelines for setting up static-free work stations, and materials and equipment needed to maintain antistatic protection, companies have used antistatic polyethylene in curtains surrounding HEPA filters to greatly reduce the adherence of particles.

Cleanroom control techniques.

Microclean Garments

Microclean garments are made of a soft, nonwoven material that is capable of blocking more than 99 percent of all particulate matter smaller than 0.5 micrometer, a millionth of a meter, which comes from people who work in cleanroom facilities. The garments are disposable, eliminating the costs of repairing and processing reusable garments. The apparel protects the product from the people and, where pertinent, protects people from the product or from certain chemical hazards. The product line includes pullover hoods, caps, coveralls, and "high top" shoe covers that reach all the way to the knees. These garments meet increasingly stringent cleanroom operating requirements in aerospace, electronics, pharmaceuticals, and medical equipment manufacturing.

Microclean garments.

Biological Isolation Garment

Prior to lunar explorations, a biological isolation garment was developed by NASA to prevent possible contamination of the Earth's atmosphere or recovery personnel with possible unknown microbial life forms brought back from the Moon. The garment became of great interest to medical researchers in the area of immunodeficiency and aplastic anemia. The NASA was contacted by the National Cancer Institute regarding usage of the garment for patients receiving chemotherapy treatment for leukemia. Baylor College of Medicine, at the Texas Medical Center, requested a germ-free suit for "David," a child born with severe immunodeficiency. The NASA developed the garment as an adjunct to patient isolation rooms, to become an extension of the protected environment. The garments can be used in hospitals having isolation rooms installed to treat leukemia, radiation injuries, burns, respiratory diseases, organ transplant patients, and immunodeficient children.

Sterilization of Hospital Equipment

Technology was developed by NASA to sterilize the Viking spacecraft using a dry-heat technique. Experience in the space program showed that an entire mission could fail because of contamination. This technology has been used by many hospitals for decontaminating hospital oxygen systems. These systems are contaminated from previous patient use. Chemical disinfectants remove most of the micro-organisms, but the few that are left multiply rapidly in the humid oxygen. A NASA laboratory helped redesign one manufacturer's equipment using space-type plastics and new methods of sealing compartments.

COOLING SYSTEMS

Cooling Garments

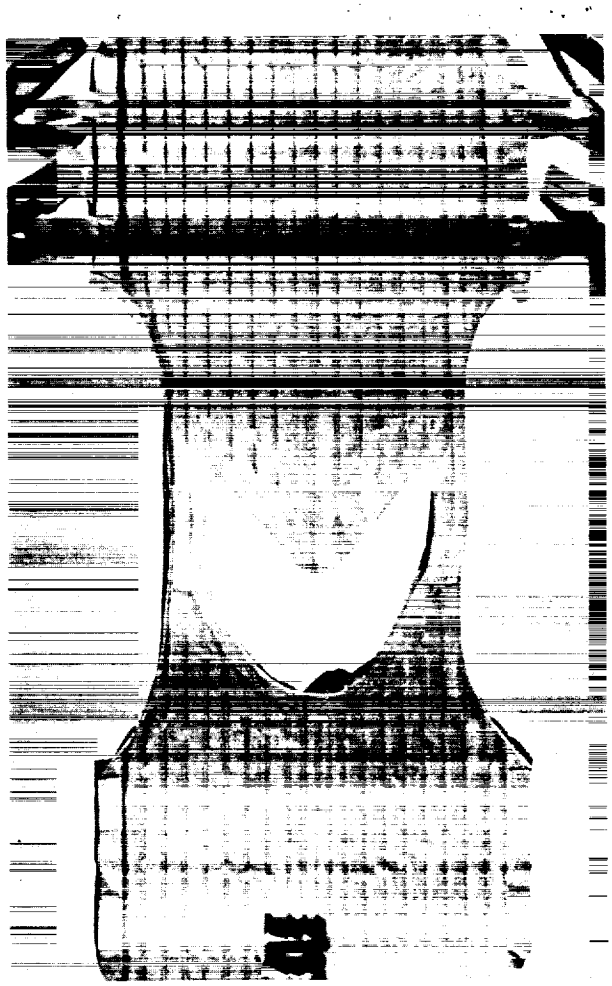
A special astronaut suit was developed by NASA to solve the heat problem of working on the Moon, which has no atmosphere and a temperature that rises as high as 250° F. The suit had a nylon outer layer supporting an inner network of tubing. Cool water flowing through the tubes kept the astronaut comfortable. The garment accommodated high heat production in the suit as a result of high EVA workloads and provided comfort, perspiration absorption, and heat transfer.

Cooling vests have been developed from NASA technology for use by quadriplegics, who often are unable to tolerate heat stress because of their inability to perspire below the level of spinal injury. These vests also are used by people working in high-temperature industrial environments. The vest is made of urethane-coated nylon and circulates chilled water throughout the lining by means of a small battery-powered pump. A pocket, which can be attached to the back of the vest or to a wheelchair, contains the pump, the battery, and the coolant, which can be ice or a frozen gel. A mechanical valve/sensor controls the waterflow and keeps the temperature at a constant 68° F.

Cooling vest and battery-powered unit.

Burning limb syndrome is a disease which causes pain in the limbs and is relieved only by cooling. Based on NASA technology developed for astronauts' spacesuits, the Ames Research Center devised a pump-chilling system which circulates cool water through a garment wrapped around a patient's thighs. The system is attached to a wheelchair, which gives the patient mobility.

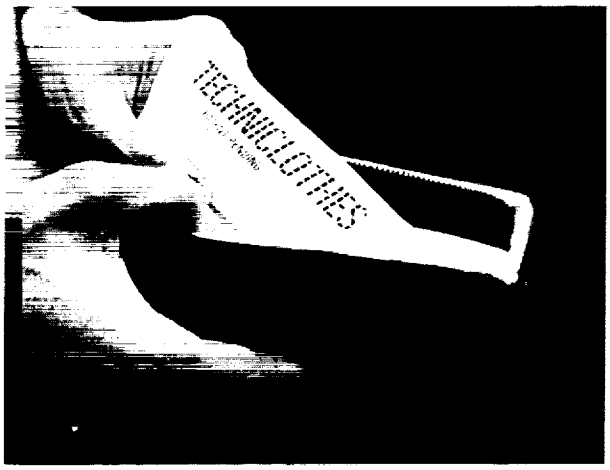
Another rare disease which causes scaling of the outer skin results in a lack of normal heat loss. Using the same technology, Ames Research Center designed a personalized, portable, battery-powered cooling unit and upper body garment. A fluid reservoir and a pump circulates cool fluid through a network of panels in the garment and allows the patient freedom from dependence on an air-cooled environment.



Cooling vest.

Cool Sportswear

The NASA liquid-cooled garment technology was adapted for athletic sportswear containing a heat-absorbing gel, a more efficient version of the "blue ice" sold for use in picnic coolers. The gel packet slips into an insulated pocket of the sportswear and is placed near parts of the body at which heat transfer is most efficient such as the forehead, the neck, or the wrist. A gel packet is effective for about an hour and can be replaced from a supply of spares in an insulated container worn on the belt. This sportswear is used mainly by runners and joggers but can be used by any athlete whose performance may be affected by hot weather.



Cool sportswear.

Scalp Cooler

Treatment of cancer with chemotherapeutic drugs usually causes hair loss in patients and thus produces emotional distress along with the physiological difficulty. A method of cooling the scalp was developed by which the amount of drugs absorbed by hair follicles is reduced and hair loss is prevented. A covering for the head holds a network of flexible plastic tubing through which cold water is pumped. A thermistor and a controller regulate the cooling temperature within preset limits. The scalp is cooled before, during, and after drug administration; the cooling time is determined by the type of drug, the dosage, and other factors.

Scalp cooler.

Personal Cooling System

A personal cooling system was developed for people subjected to heat stress in such occupations as small aircraft piloting, auto racing, operating heavy equipment, deep mining, and the metal, chemical, paper, and glass industries. The system consists of a lightweight vest with a liquid-cooling network of plastic tubes, a cooling headliner in a helmet, and a portable cooling package. The cooling package includes a heat exchanger which cools the liquid in the vest and headliner, a control display unit containing a pump, a liquid reservoir, and a temperature control and power unit. It can be operated from its own rechargeable battery or from an airplane or vehicle power system.

Personal cooling system.

LUNAR ROVER TECHNOLOGY

Vehicle for the Handicapped

A vehicle controller system was developed to allow handicapped people to drive vehicles. The system is based on the NASA technology developed for the lunar roving vehicle. A joystick performs the functions of steering wheel, brake pedal, and throttle pedal so that it can be used by people who have no lower limb control and only limited use of upper extremities. The driver moves the joystick forward to accelerate, backward to brake, and from side to side for steering. The system is designed as an addition to an ordinary van. The digital electronics, microprocessors, and high-torque actuators are easily installed under the dashboard as "bolt-on" accessories. A push of a button switches from the vehicle's normal control to this system's control.

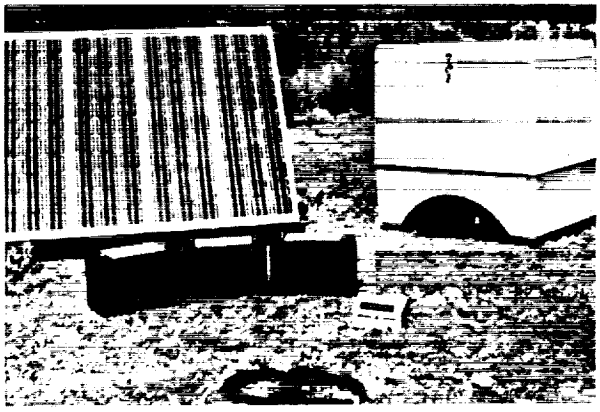
Vehicle for the handicapped.

SOLAR ENERGY

Solar Equipment

Sunlight is converted directly into electricity by the use of photovoltaic cells. The performance of photovoltaic conversion to provide power for equipment aboard spacecraft was improved upon by NASA. Solar-powered refrigerators developed from NASA technology were installed in villages in Africa, Asia, the Caribbean, South America, and Central America to provide refrigeration of vaccines in clinics. Vaccines are used extensively to control such communicable diseases as poliomyelitis, diphtheria, and measles, but lack of refrigeration can cause the vaccines to lose potency. Conventional electric service in rural areas of developing countries is often unreliable or nonexistent. It is estimated that three-fourths of the people in developing countries do not have

adequate refrigeration, a fact that seriously hampers disease control by vaccination. The solar-powered refrigerators may be forerunners of many more solar-powered systems for medical storage applications.



Solar-powered refrigerators.

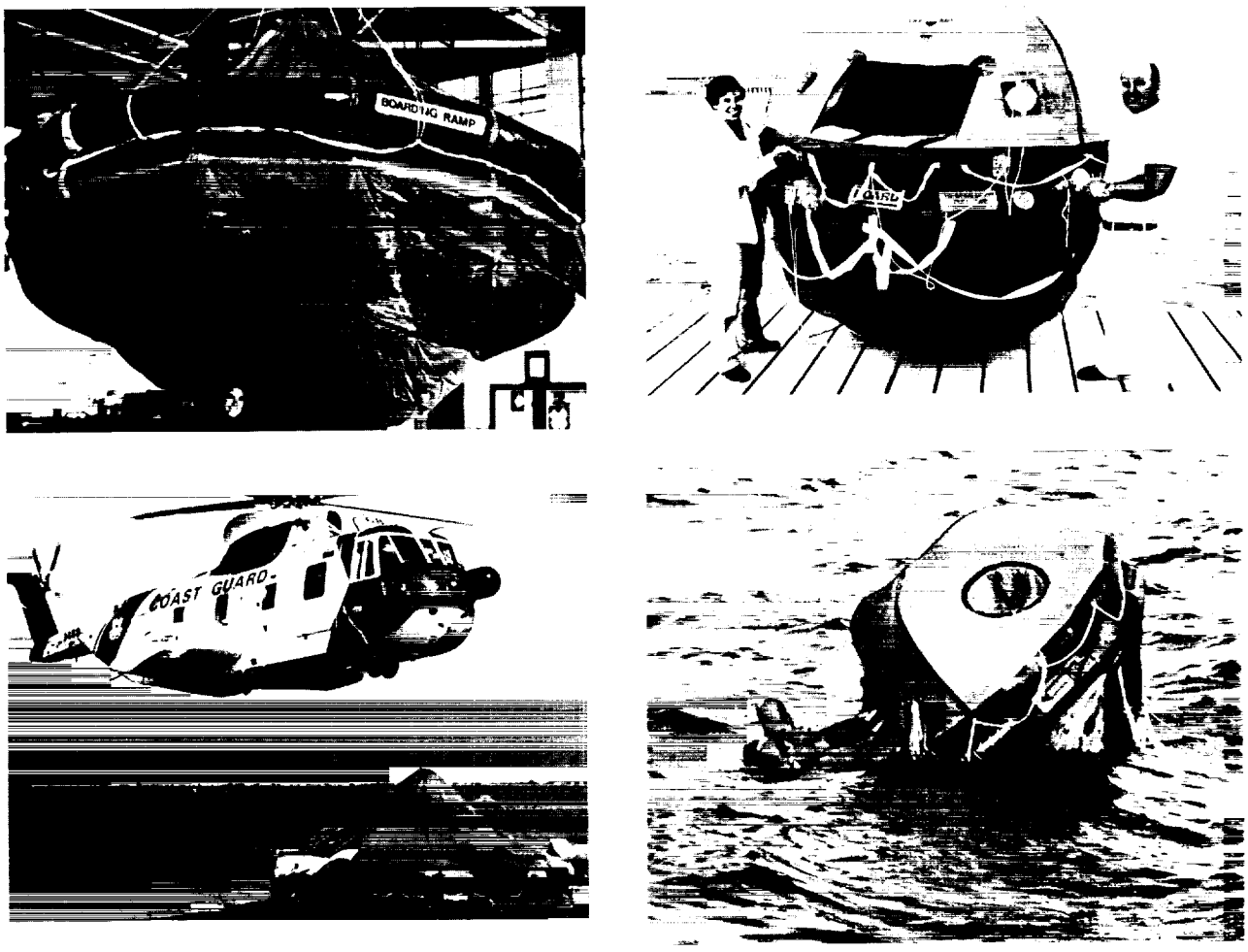
Designed for trail guards who work for the Inyo National Forest, a backpack system containing a lightweight solar cell pack to charge batteries for portable two-way radios was developed by the NASA Lewis Research Center. The guards, who are on patrol for as much as 2 weeks at a time, need continuous communication with the District Station, but battery capacity precludes such operation. With the solar cell supply, the guards can use their radios 24 hours a day.

A technique was developed to decrease the number of exposures to harmful x-rays required for detection of some diseases. Solar cells are sensitive to light as well as to x-rays. When a solar cell sensor is positioned directly beneath the x-ray film, it can determine exactly when the film has received sufficient radiation and has been exposed to optimum density. At that point, associated electronic equipment sends a signal to cut off the x-ray source. When several small solar cells are connected electrically so that their outputs are additive, they can sense extremely small amounts of x-ray energy. Placing a fluorescent material in contact with the solar cell surface increases sensitivity even further.

ASTRONAUT RETRIEVAL

Self-Righting Liferaft

During the Apollo and Skylab Programs, ocean-landed astronauts left their command modules and waited in inflatable rafts for pickup by helicopter. The NASA found that improperly ballasted, flat-bottomed rafts tended to overturn under the force of the helicopter's downwash. The NASA Lyndon B. Johnson Space Center developed a new method of raft stabilization which was used as a basis for a newly designed self-righting liferaft. This raft is designed to prevent capsizing in rough water or under pressure of rotor downwash when helicopters are used in rescue operations. A large hemisphere-shaped underwater chamber provides exceptional stability by admitting 4800 pounds of water for ballast through a flapper valve. The chamber moves with the wave action to prevent raft overturning or blowing away in high winds. The raft also rights itself if accidentally inflated upside down. The stabilization system compensates for changes in wave angle and for weight shifting as raft occupants move about. The raft cannot overturn in normal seas, and, if it is hit by a wave, it somersaults and rights itself.



Self-righting liferaft.

INDEX

Spinoff	*Developers*	*Page*
Visual Alert System	NASA/LaRC; "Visual Alerting System," Grace Industries, Inc., Transfer, PA	10
Vital-2 Blood Pressure Device	Meditron Instrument Corp., Milford, NH	19
Voice-Controlled Wheelchair and Manipulator	NASA/JPL	20
Weight Alleviation Device	NASA/LaRC; Research Triangle Institute, NC	25
X-ray Energy Sensor	NASA/JPL	46
X-ray Image Refinement	NASA/GSFC	14

NASA CENTERS

ARC - Ames Research Center, Moffett Field, CA

GSFC - Goddard Space Flight Center, Greenbelt, MD

JPL - Jet Propulsion Laboratory, Pasadena, CA

JSC - Lyndon B. Johnson Space Center, Houston, TX

LaRC - Langley Research Center, Hampton, VA

LeRC - Lewis Research Center, Cleveland, OH

MSFC - George C. Marshall Space Flight Center, Huntsville, AL

☆ U.S. GOVERNMENT PRINTING OFFICE: 198- -761-013/60285